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ORIGINAL ARTICLE

A comparative study of cone-beam CT and multidetector CT in the preoperative assessment of odontogenic cysts and tumors

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KEYWORDS

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Abstract *Aim of the work:* To compare the accuracy of cone beam CT (CBCT) and multidetector CT (MDCT) in the preoperative radiological assessment of odontogenic cysts and tumors.
Material and methods: This prospective study included 24 patients (13 males and 11 females) with primary untreated pathologically proven odontogenic cysts and tumors. Their ages ranged from 5–45 years. They underwent (CBCT) and (MDCT). All CBCT and MDCT images were reviewed for morphologic characteristics of the lesions, internal appearance, extension as well as effect on surrounding structures. All patients were scheduled for surgical treatment within one week after clinical and radiological evaluation. Using intra-operative findings as the gold standard, the accuracy of (CBCT) and (MDCT) for radiological assessment of odontogenic cyst and tumors was compared.
Results: Histopathologic examination established that of the 24 tumors; 10 were radicular cyst, five dentigerous cyst, three amelobalstoma, three odontogenic keratocyst, one buccal bifurcation cyst, one nasopalatine cyst, and one lateral periodontal cyst. Both CBCT and MDCT were identical in detecting location, borders and internal structure of examined lesions. Concerning linear measurements of the lesions, MDCT underestimated mean depth by 1.7 mm and CBCT underestimated it

Abbreviations: CBCT, cone beam computerized tomography; MDCT, multidetector CT; MPR, multiplanar reformation; MIP, maximum intensity projection; SSD, shaded surface display

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by 0.9 mm. MDCT underestimated the mean width by 0.9 mm, and CBCT underestimated it by 0.7 mm. MDCT overestimated the mean height by 1.7 mm and CBCT overestimated it by 1 mm. CBCT was superior than MDCT in detecting thinning and perforation of buccal cortical plate and displacement of teeth.

Conclusion: In the overall assessment of odontogenic cysts and tumors, CBCT was comparable with MDCT with no significant statistical difference ($P < 0.05$). However, CBCT was more accurate in linear measurements and identification of tooth displacement and buccal bone defect. It is an optimal radiological modality for preoperative radiological assessment of odontogenic tumors.

1. Introduction

Lesions that occur in the mandible and maxilla, may be odontogenic or nonodontogenic. Most odontogenic lesions are benign, but some may exhibit aggressive and destructive behavior locally (1,2).

Careful examination of the maxillo-facial lesion and their relationship with surrounding anatomical structures is essential before performing oral surgery. Clinicians require exact knowledge of the morphology and extension of the lesions in order to determine the appropriate type of the treatment planning (3,4).

Preoperative radiological evaluation of odontogenic lesions when done carefully can help to avoid surgical complications and postsurgical functional impairment, and reduce surgical stress. Neither intraoral nor panoramic radiographs give the three-dimensional (3D) information of the imaged area needed for optimal preoperative planning. Different cross-sectional tomograms, CT and, more recently, cone beam CT (CBCT) examinations have been used for this purpose (1,5,6).

The introduction of multidetector computed tomography (MDCT) represented a fundamental evolutionary step in the development of CT imaging techniques. MDCT scan can yield multiple, thin, overlapping slices that can be rapidly reconstructed, resulting in higher-quality images. Special algorithms allow multiplanar computer-reformatted 3-dimensional (3D) and panoramic reconstructions (7,8).

Recently, Cone-beam computed tomography (CBCT) stands out as an alternative to MDCT. This recently-designed technology became a relevant tool for oral and maxillofacial diagnostic osseous imaging. It allows the creation in "real time" of images in the axial, coronal, sagittal and oblique or curved image planes. In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3D-dimensional information. The benefits of CBCT are smaller device size, short scanning times, and low acquisition costs, and lower radiation dose than MDCT (9,10).

The purpose of this study was to compare the accuracy of cone beam CT (CBCT) and multidetector CT (MDCT) for preoperative radiological assessment of odontogenic cyst and tumors using direct intra-operative findings as a gold standard of reference.

2. Patients and methods

2.1. Study population

During the period between February 2010 and July 2012, 24 consecutive patients (13 males and 11 females) with primary untreated pathologically proven odontogenic cysts and tumors were included in this prospective study. The patients aged 5–45 years. All patients were submitted to dental and medical history taking as well as clinical examination including extra and intraoral examination. Histopathological diagnosis was established by means of aspiration which was performed for all lesions, and incisional biopsy which was performed for 14 patients. All patients underwent CBCT and MDCT. All patients were scheduled for surgical treatment within one week after historic, clinical, pathological and radiological evaluation. This study was approved by the ethics committee of our institution.

2.2. Eligibility

Patients were eligible to be included in this study after clinical and pathological confirmation of odontogenic cyst or tumors. Exclusion criteria include: non-odontogenic lesions, postsurgical recurrent cysts and lesion with large extra-osseous extension to the soft tissue.

2.3. Cone beam computerized tomography (CBCT)

All patients were scanned using (Scanora 3D, Sorredex- Finland) a Flat Panel based CBCT machine. The device was operated at 7 mA, 85 kV, 0.5 mm focal spot, five degree target angle, 0.16-mm voxel size and a typical exposure time of 5.4 s. Upon completion, the image was processed using application software (Cybermed –Korea) with SCANORA 3D visualization. MPR (Multi-Planar Reformat), panoramic and cross-sectional views were performed. The DBM (Database Manager) provided with the system was used to store images on CD/DVDs including a DICOM CD Viewer.

2.4. Multidetector (MDCT)

All MDCT examinations were performed using 16 detector CT scanner (GE bright speed). The patient was placed supine on the scanner table, the head was positioned as symmetrically as possible, and the neck slightly extended. The patient was instructed not to move or swallow during scanning. Simultaneous MDCT scanning was performed, first, a lateral scout view (topogram) was taken and used for planning the axial images. Axial images were taken parallel to the occlusal plane of the maxilla. The following parameters were used, kV 120, slice thickness 0.5 mm, scanning time 7–10 s, pitch one, matrix size 512 × 512, field of view (FOV) 180 mm, and reconstruction interval 0.5 mm. No contrast was used. The axial source images transferred to an Advantage Workstation (AW) volume share two and multiplanar reconstructions were generated using the included standard dental software package. The panoramic and paraxial images were obtained perpendicular to the transverse images. Then multi-planar reformation (MPR), maximum intensity projection (MIP) and shaded surface display (SSD) were done in different planes.

2.5. Image analysis

All CBCT and MDCT source and postprocessing images were reviewed in consensus by two radiologists (diagnostic radiologist and oral-maxillofacial radiologist). Both had no contact with the specimens and were blinded to patient's clinical information. Images of both modalities were reviewed for morphologic characteristics including: origin, greatest diameters (depth, height and width), margin (smooth or irregular), lesion shape (round, ovoid, or lobular), internal appearance (homogeneous or heterogeneous), internal structure (fluid, soft tissue, lytic, sclerotic, mixed, and calcification), extension as well as effect on surrounding structures (thinning and/or perforation of buccal or lingual cortex, involvement of the maxillary sinus, teeth or alveolar canal displacement).

2.6. Surgical intervention

Surgical treatment for all lesions was scheduled on the bases of history, clinical examination, radiological diagnosis and pathological confirmation. The same surgeon performed all operations, he assessed each lesion intra-operatively, regarding its size, extension, relationship and its effect on the surrounding structures. The dimensions of the lesion (length, width & depth) were measured using a specialized millimeter caliper and the mean of measurement was calculated.

2.7. Statistical analysis

Outcome information were obtained by reviewing CBCT, MDCT findings, final surgical and pathology reports of each patient. Intra-operative findings and pathological outcome were the gold standard for the collected data analysis. McNemar's test was used firstly for comparison between the two modalities, secondly for comparison between the two modalities and intra-operative findings. Quantitative data were presented as mean and standard deviation values. The significant level was set at $P \leqslant 0.05$. Statistical analysis was performed with PASW Statistics 18.0 (Predictive Analytics Software) for Windows.

2.8. Results

This study included 24 patients with primary untreated pathologically proven odontogenic cysts and tumors (the patients aged 5–45 years). Of the examined 24 swellings, 21/24 (87.5%) were painless, 3/24 (12.5%) were painful, 2/24 (8.3%) comprisable, 22/24 hard (91.6%), and 4/24 (16.6%) with teeth displacement. Of the included 24 patients 4 (16.6%) complained of facial disfigurement, and 2/24 (8.3%) lip parathesia. Histopathological diagnoses were 10/24 (41.6%) radicular cyst, 5/24 (20.8%) dentigerous cyst, 3/24 (12.5%) amelobalstoma, 3/24 (12.5%) odontogenic keratocyst, 1/24 (4.1%) buccal bifurcation cyst, 1/24 (4.1%) nasopalatine cyst, and 1/24 (4.1%) lateral periodontal cyst. Table 1 shows pathological outcome of the included odontogenic lesions.

Both modalities (CBCT and MDCT) were identical in detection of location, borders and internal structure of examined lesions. Likewise, there was no statistically significant difference regarding comparison between the latter modalities and intra-operative findings ($P = 1.000$). All included lesions were single, 7/24 (29.1%) in the maxilla, 17/24 (70.8%) in the mandible, 19/24 (79.1%) well-defined borders, 5/24 (20.8%), ill-defined borders, 22/24 (91.6%) radiolucent, and 2/24 (8.3%) mixed. Fig. 1

Regarding linear measurement: MDCT showed lower mean lesion depth and width. The mean lesion depth measured by CBCT was 24.2 (±11.1) mm, by MDCT was 23.4 (±9.8) mm and by intra-operative measurement was 25.1 (±11.9) mm. MDCT underestimated the mean depth by 1.7 mm and CBCT underestimated the mean depth by 0.9 mm. The mean lesion width measured by CBCT was 22.4 (±8.6) mm, by MDCT was 22.2 (±8.6) mm and was 23.1 (±9.8) mm as measured intra-operatively. MDCT underestimated the mean width by 0.9 mm, and CBCT underestimated the mean width by 0.7 mm. The mean lesion height measured with CBCT was 25.3 (±12.2) mm, with MDCT was 26 (± 12.6) mm and intra-operatively was 24.3 (±11.1) mm. MDCT overestimated the mean height by 1.7 mm and CBCT overestimated the mean height by 1 mm. Results are shown in Table 2. Figs. 2–5.

Table 1 Pathology outcome of 24 included odontogenic lesions.

Pathology outcome	%
Radicular cyst	10/24 (41.6%)
Dentigerous cyst	5/24 (20.8%)
Amelobalstoma	3/24 (12.5%)
Odontogenic keratocyst	3/24 (12.5%)
Buccal bifurcation cyst	1/24 (4.1%)
Nasopalatine cyst	1/24 (4.1%)
Lateral periodontal cyst	1/24 (4.1%)

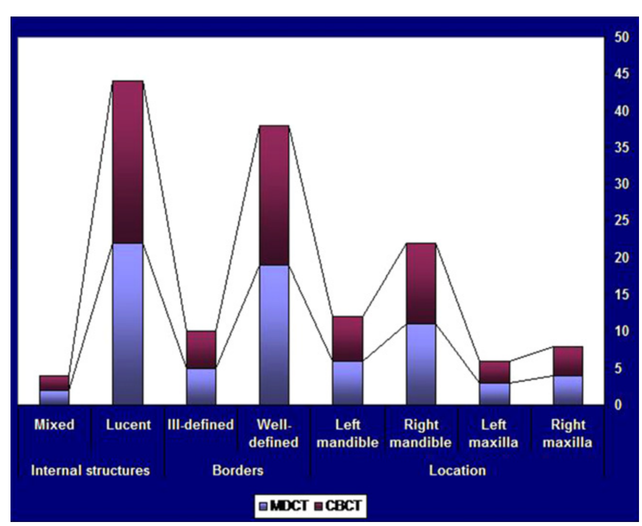

Fig. 1 Shows that both CBCT and MDCT were identical in detecting location, borders and internal structure of the examined odontogenic lesions.

Table 2 The mean lesion diameters in MDCT, CBCT and intra-operative measurements.

	Mean and standard deviation (SD) values		
	Depth	**Width**	**Height**
CBCT	24.2 mm (±11.1)	22.4 mm (±8.6)	25.3 mm(±12.2)
MDCT	23.4 mm(±9.8)	22.2 mm (±8.6)	26 mm (±12.6)
Intra-operative	25.1 mm (±11.9)	23.1 mm (±9.8)	24.3 mm (±11.1)
***P*.Value**	0.0001	0.014	0.001

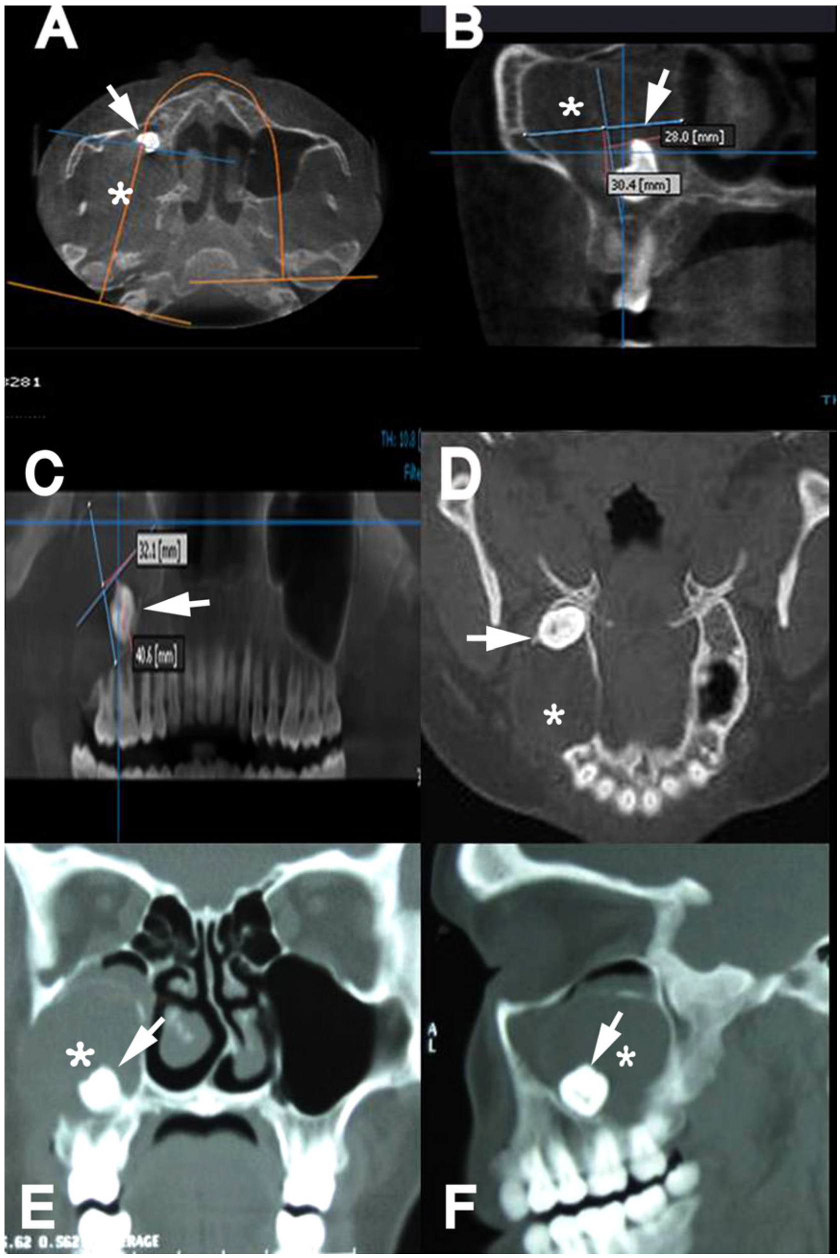

Fig. 2 Odontogenic keratocyst. *CBCT: A–C* (axial, coronal, and panoramic reformatted images, respectively). *MDCT: D–F* (axial, coronal MIP and sagittal oblique MIP images, respectively) show cystic expansile lesion involving the right maxilla (*asterisk*). It showed well-defined, thin corticated borders and vertically impacted unerupted upper first molar (*arrows*). Both modalities were identical in the detection of lesion location, internal structure, and cortical thickening.

Compared with intraoperative findings, CBCT was superior than MDCT in detecting thinning and/or perforation of buccal cortical plate and displacement of teeth. The former was detected by CBCT in 12/24 patients (50%), in 11/24 patients

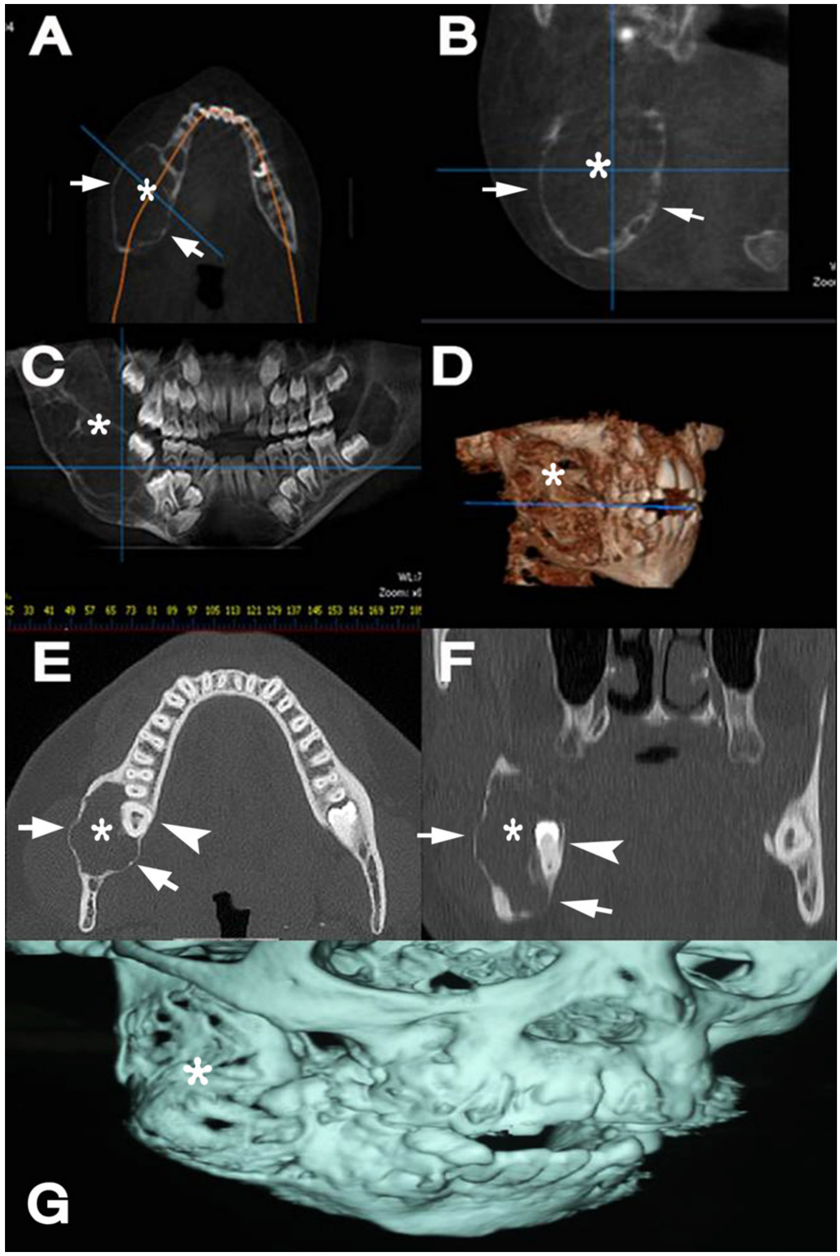

Fig. 3 Ameloblastoma. *CBCT: A–D* (axial, coronal, panoramic reformatted and 3D images, respectively). *MDCT: E–G* (axial, coronal MIP and 3D volume-rendering images, respectively). Both modalities were identical showing well-circumscribed radiolucent lesions involving the right mandibular ramus (*asterisk*) with tooth displacement (*arrow heads*). Both buccal and lingual plates were expanded, scalloped and thinned with no evident erosion (*short arrows*).

(45.8%) using MDCT, and in 14/24 (58.3%) during intra-operative exploration. Displacement of teeth was detected in 12/24 patients (50%) using CBCT and during intraoperative exploration, whereas MDCT detected 10/24 patients (41.6%) with teeth displacement. Both modalities as well as intra-operative findings detected expansion of buccal and/or lingual cortical plate in 9/24 patients (37.5%), involvement of the maxillary sinus in 3/24 patients (12.5%), displacement of inferior alveolar canal in 1/24 patient (4.1%), flaring of central incisors roots in 1/24 patient (4.1%) and looseness of lateral incisor in 1/24 patient (4.1%). Results are tabulated in Table 3, Figs. 2–5.

3. Discussion

Radiology is important in the diagnostic assessment, treatment planning and follow-up of patients suspected of having dental and maxillofacial disease (1,2). Several intraoral and extraoral radiographic methods such as periapical, occlusal, panoramic, and motion tomography are commonly available for evaluation of those patients. However, some of the drawbacks of these techniques are superimposition, poor visualization, and distortion of other anatomic structures. Nowadays, the introduction of MDCT and CBCT provides the most accurate

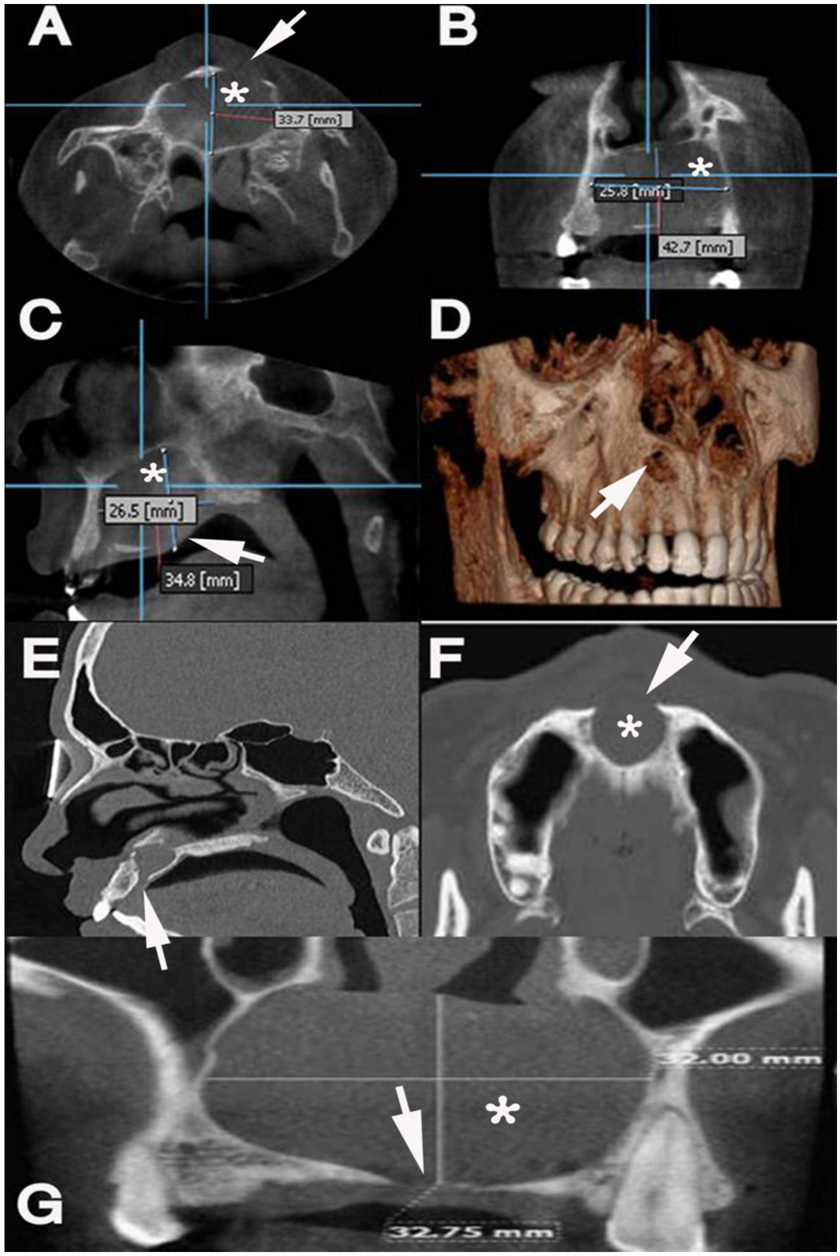

Fig. 4 Nasopalatine cyst. *CBCT: A–D (*axial, coronal, sagittal and 3D images, respectively). *MDCT: E–G* (sagittal oblique MIP, axial, and magnified coronal MIP images, respectively). Both modalities showed round radiolucency with well-defined borders (*asterisk*)*,* and both cortical plate defect (*arrows*). Both were identical in detection of location, internal structures, as well as cortical defect, however regarding dimensions MDCT overestimated the lesion height by 3 mm and CBCT overestimated it by 1 mm. MDCT underestimated the lesion width by 2.2 mm, and CBCT underestimated it by 0.5 mm.

modalities for preoperative evaluation of the maxillofacial region. Each allowed careful preoperative evaluation of the maxillo-facial lesions, their relations and extensions (8–10).

We conducted our study aiming to compare the diagnostic accuracy of CBCT and MDCT in preoperative radiological evaluation of odontogenic cysts and tumors. This was in line with ***Nakagawa*** **et al.** (9) who reported that preoperative radiological evaluation of odontogenic lesions avoids surgical complications, post-surgical functional impairment, and reduces surgical stress. ***Kobayashi*** **et al.** (11) reported that a deeper knowledge of the diagnostic accuracy potential of different radiological modalities and their application will allow optimization of the preoperative planning. ***Mortele*** **et al.** (7) highlighted that comparative study between two radiological modalities helps maximize the diagnostic strength of these modalities and develop a modality that can significantly improve the radiological diagnosis.

In the present study, there was no significant statistical difference between the two modalities in interpreting the internal structures of the lesions. Several reports have alluded to this concept. ***Nakagawa*** **et al.** (9) reported that CBCT clearly visualized the internal structure of the mandibular tumor, and tu-

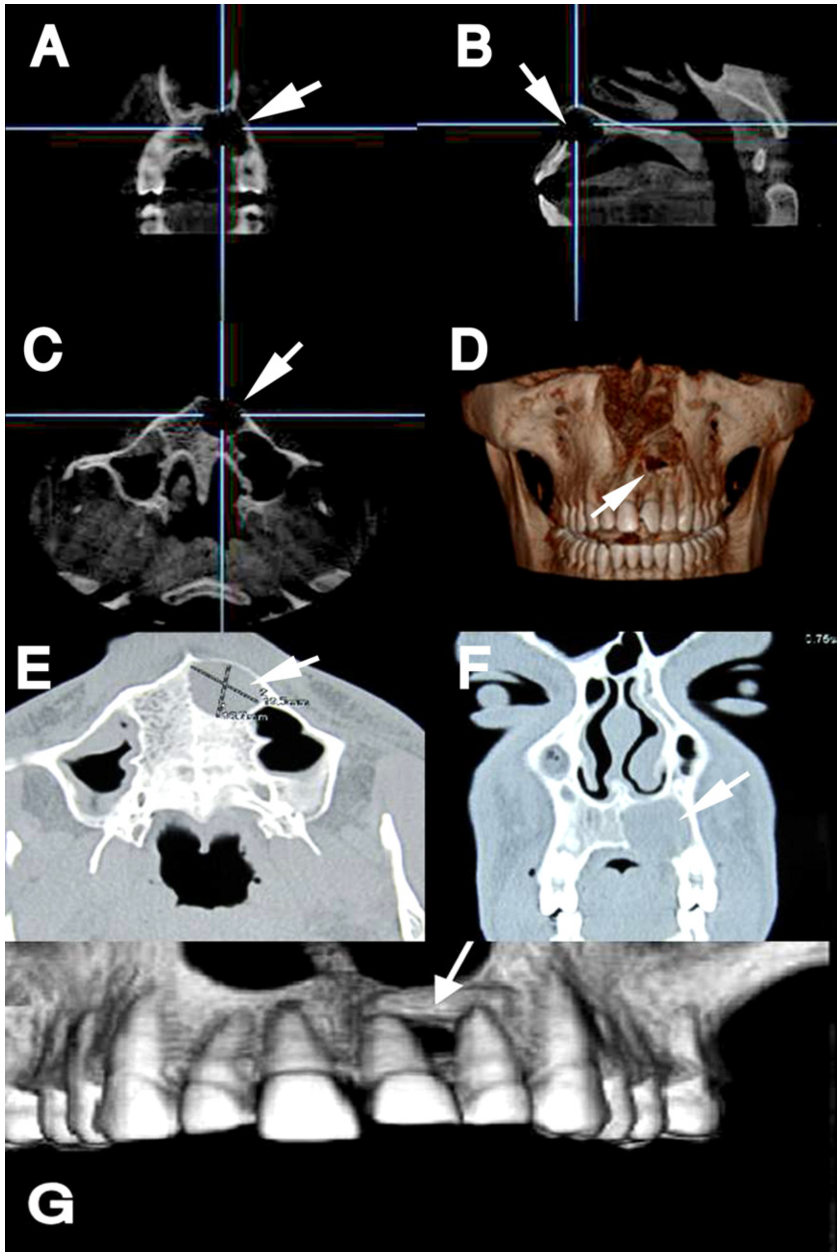

Fig. 5 Radicular cyst. *A–D* (A: coronal, sagittal oblique, axial and 3D: volume-rendering images, respectively). *MDCT: E–G* (axial, coronal MIP and 3D volume-rendering images, respectively). Both modalities showed well-defined radiolucent lesion related to the root of tooth 21(*arrows*). Both modalities were identical.

mor expansion to both buccal and lingual cortical bones. ***Kazunori*** **et al.** (12), analyzed the morphologic features of 92 odontogenic cysts by CT and reported that CT was highly accurate in assessment of morphological changes of odontogenic cysts. ***Trope*** **et al.** (5) concluded that odontogenic cyst could be differentiated from periapical granulomas by CT because of a marked difference in density between the content of the cyst cavity and granulomatous tissue. ***James*** **et al.** (13) concluded that CBCT may provide an accurate, faster method to differentiate a solid from a fluid filled lesion or cavity.

In the present study, direct intraoperative measurements of the mean lesion diameters were 25.1 ± 11.9 mm depth, 23.1 ± 9.8 mm width, and 24.3 ± 11.1 mm height. MDCT defined the mean lesion diameters to 23 ± 9.8 mm, 22 ± 8.6 mm, and 26 ± 12.6 mm, depth, width, and height respectively. It underestimated the mean depth by 1.7 mm, mean width by 0.9 mm, and overestimated the mean height by 1.7 mm. On the other hand CBCT defined the mean lesion diameters to 24.2 ± 11.1 mm, 22.4 ± 8.6 mm, and 25.3 ± 12.2 mm, depth, width, and height respectively. It underestimated the mean depth by 0.9 mm, mean width by 0.7 mm, and overestimated the mean height by 1 mm.

Our results showed no significant statistical difference between CBCT and MDCT regarding linear measurement of odontogenic cysts and tumors. Furthermore both modalities were correlated well with the intra-operative findings regarding

Table 3 Effects on surrounding structures as shown by the two modalities compared with intra-operative findings.

	CBCT	MDCT	Intra-operative	[a]*P-Value*	
				Intra-operative vs. CBCT	*Intra-operative vs. MSCT*
Thinning and/or perforation of buccal cortical plate	12/24(50%)	11/24(45.8%)	14/24(58.3%)	*P = 0.974*	*P = 1.000*
Thinning and/or perforation of palatal (lingual) cortical plate	9/24(37.5%)	9/24(37.5%)	7/24(29.1%)	*P = 0.219*	*P = 0.219*
Expansion of buccal and/or lingual cortical plate	9/24(37.5%)	9/24(37.5%)	9/24(37.5%)	*P = 1.000*	*P = 1.000*
Involvement of maxillary sinus	3/24(12.5%)	3/24(12.5%)	3/24(12.5%)	*P = 1.000*	*P = 1.000*
Displacement of teeth	12/24(50%)	10/24(41.6%)	12/24(50%)	*P = 0.974*	*P = 1.000*
Displacement of inferior alveolar canal	1/24(4.1%)	1/24(4.1%)	1/24(4.1%)	*P = 1.000*	*P = 1.000*
Flaring of central incisors roots	1/24 (4.1%)	1/24 (4.1%)	1/24 (4.1%)	*P = 1.000*	*P = 1.000*
Looseness of lateral incisor	1/24(4.1%)	1/24(4.1%)	1/24(4.1%)	*P = 1.000*	*P = 1.000*

[a] Significant at $P \leqslant 0.05$.

the estimation of the depth, width and height of the lesion in axial, coronal and sagittal views with no significant statistical difference ($p = 0.0001$ for mean lesion depth, $P = 0.014$ for mean lesion height and $P = 0.001$ for mean lesion width)

Our findings extended prior data which established the accuracy of CBCT in linear, volumetric, and angular measurements of maxillofacial structures.(14,15,11) ***Vasconcelos* et al.** (16) compared periapical radiographs with CBCT in detecting linear measurement of alveolar bone defect, they concluded that CBCT was the only method that allowed for an analysis of the buccal and lingual/palatal surfaces and for improved visualization of the morphology of the defect. ***Rudolf* et al.** (17) compared sensitivity of CBCT and MSCT for linear measurement of cortico-trabecular bone defects of the maxillofacial area, they reported that CBCT could detect smaller bone defects than MDCT. ***Pinsky* et al.** (14) investigated the accuracy of CBCT in linear measurements of bone defects and concluded that CBCT is an accurate diagnostic tool for small osseous defects evaluation. ***Gaia* et al.** (10) compared the accuracy of MDCT and CBCT for evaluation of lesions in the maxillofacial region, they reported that CBCT and MDCT showed similar results in depicting the percentage of cortical bone involvement, with great sensitivity and specificity. ***Hasimoto* et al.** (18) concluded that for tooth and bone structures CBCT was considered to have yielded higher image quality and reproducibility than 4-row MDCT.

This was not in agreement with ***Loubele* et al.** (19) who compared the CBCT and MDCT for linear jaw bone measurements, they concluded that both CBCT and MSCT yield submillimeter accuracy for linear measurements, this could be explained by using an ex-vivo formalin-fixed human maxilla. ***Lopes* et al.** (8) demonstrated high accuracy of 3D-CT in the analysis of angular measurements for dentofacial applications, this could be explained by that they used 64-row multislice CT.

In the present study, both modalities showed no statistically significant difference in assessment of effect of odontogenic lesions on surrounding structures ($p < 0.005$). However there was an overall higher accuracy for CBCT than MDCT for the detection of thinning and/or perforation of buccal cortical plate and displacement of teeth. Otherwise, both modalities showed same accuracy for detecting thinning and/or perforation of palatal (lingual) cortical plate, expansion of buccal and/or lingual cortical plate, involvement of the maxillary sinus, displacement of inferior alveolar canal, and flaring of central incisor roots.

These results go in coherence with those achieved by several authors. ***Vandenberghe* et al.** (20) reported that CBCT allowed more accurate assessment of periodontal bone loss. ***Noujeim* et al.** (21) assessed the accuracy of CBCT in the detection of periodontal bone loss, their results indicated that the CBCT has better accuracy and diagnostic value in the detection of interradicular periodontal bone defects. ***Nakayama* et al.** (22) reported that CT cannot precisely detect an early weak bone invasion, or infiltrating through the trabecular bone.

In the present study CBCT was very helpful in good preoperative planning and preparation as it helped in deciding the best approach for lesion enucleation and the incisions were precise to include the lesions. It was very helpful in estimating the amount of bone graft needed and prepared preoperatively. It allowed a careful assessment of the relationship between the large lesions and close vital structures such as maxillary sinus, nasal cavity, and mandibular neurovascular bundle.

These findings are consistent with previous studies that described the preoperative application of cone beam computed tomography as an assessment tool before oral surgeries. **Marques et al.** (23) reported that CBCT provided the surgeon with vital information necessary for planning surgery. ***Nakagawa* et al.** (9) reported that cone beam CT accurately assessed the relationship between the lesions and their adjacent anatomical structures, it was useful in estimating the relationship of the lesion to the adjacent teeth and nasal floor and gives superior information for preoperative evaluation of dento-alveolar surgery.

In the present study, the effective radiation doses from MSCT imaging were clearly higher than those from CBCT imaging. Depending on our diagnostic target and used scan settings and parameters of each modality, the effective dose of CBCT showed reductions ranged from 3 to 4 times lower than that of MDCT. This could be explained by the fact that beam collimation of the CBCT was achieved by using small FOV (60 mm compared to 180 mm FOV used in MDCT), enables limitation of X-radiation exposure to the region of interest and lowering the overall beam geometry. ***Ludlow* et al.** (24) stated that decreasing the FOV from 12 inches to 9 inches lowered the effective doses by between 17% and 49% for different CT scanners. This advantage of low effective dose for CBCT due to using a small FOV, has disadvantage in the form of increased artifacts and lack of beam-hardening correction.

In the current study we used high spatial-resolution mode CBCT which resulted in higher spatial-resolution image quality than that of MDCT. However we found that this mode generated a rather high image noise in CBCT examination of the maxilla in which we used a low-spatial-resolution mode CBCT which resulted in a comparable contrast spatial resolution for both modalities. Also, we found that CBCT had inferior soft tissue contrast resolution and overall decreased image quality relative to MDCT scanners. This was in keeping with ***Suomalainen A* et al.** (25) who reported that flat-panel detector, significant scattering effect and lack of beam-hardening correction explained inferior soft tissue contrast resolution and overall decreased image quality of CBCT relative to that of MDCT. In the current study we did not use IV contrast because our study did not include lesion with extraosseous soft tissue extension, large malignant lesion and soft tissue lesions. The observed advantages of CBCT included: low cost, easy accessibility and low radiation dose, submillimeter resolution, high speed scanning and comfortable patient position, and its disadvantage included inferior soft tissue contrast resolution. Advantages of MDCT included bone, soft tissue and air windows, IV contrast injection could be used and disadvantages of MDCT included: high cost, and high radiation dose.

Points of weakness in our study lie on, exclusion of lesion with extraosseous extension, large malignant lesions, and soft tissue lesions as well as image analysis by two radiologists at the same sitting with consequence with lack of inter-observer variability testing.

4. Conclusion

In the overall preoperative radiological assessment of odontogenic tumors, CBCT was comparable with MDCT with no significant statistical difference in linear measurements. However, CBCT was more accurate in identification of tooth displacement as well as buccal bone defect. It is a reliable tool for preoperative radiological assessment of odontogenic cyst and tumors when compared with MDCT.

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